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PERSPECTIVE

Global warming: it's not only size that matters

Gabriele C Hegerl*School of Geosciences,
University of Edinburgh,
Edinburgh, UK
gabi.hegerl@ed.ac.uk*

Observed and model simulated warming is particularly large in high latitudes, and hence the Arctic is often seen as the posterchild of vulnerability to global warming. However, Mahlstein *et al* (2011) point out that the signal of climate change is emerging locally from that of climate variability earliest in regions of low climate variability, based on climate model data, and in agreement with observations. This is because high latitude regions are not only regions of strong feedbacks that enhance the global warming signal, but also regions of substantial climate variability, driven by strong dynamics and enhanced by feedbacks (Hall 2004). Hence the spatial pattern of both observed warming and simulated warming for the 20th century shows strong warming in high latitudes, but this warming occurs against a backdrop of strong variability. Thus, the ratio of the warming to internal variability is not necessarily highest in the regions that warm fastest—and Mahlstein *et al* illustrate that it is actually the low-variability regions where the signal of local warming emerges first from that of climate variability. Thus, regions with strongest warming are neither the most important to diagnose that forcing changes climate, nor are they the regions which will necessarily experience the strongest impact.

The importance of the signal-to-noise ratio has been known to the detection and attribution community, but has been buried in technical ‘optimal fingerprinting’ literature (e.g., Hasselmann 1979, Allen and Tett 1999), where it was used for an earlier detection of climate change by emphasizing aspects of the fingerprint of global warming associated with low variability in estimates of the observed warming. What, however, was not discussed was that the local signal-to-noise ratio is of interest also for local climate change: where temperatures emerge from the range visited by internal climate variability, it is reasonable to assume that changes in climate will also cause more impacts than temperatures that have occurred frequently due to internal climate variability. Determining when exactly temperatures enter unusual ranges may be done in many different ways (and the paper shows several, and more could be imagined), but the main result of first local emergence in low latitudes remains robust.

A worrying factor is that the regions where the signal is expected to emerge first, or is already emerging are largely regions in Africa, parts of South and Central America, and the Maritime Continent; regions that are vulnerable to climate change for a variety of regions (see IPCC 2007), and regions which contribute generally little to global greenhouse gas emissions. In contrast, strong emissions of greenhouse gases occur in regions of low warming-to-variability ratio.

To get even closer to the relevance of this finding for impacts, it would be interesting to place the emergence of highly unusual summer temperatures in the context not of internal variability, but in the context of variability experienced by the climate system prior to the 20th century, as, e.g. documented in palaeoclimatic reconstructions and simulated in simulations of the last millennium (see Jansen *et al* 2007). External forcing has moved the temperature range around more strongly for some regions and in some seasons than others. For example, while reconstructions of summer temperatures in Europe appear to show small long-term variations, winter shows deep drops in temperature in the little Ice Age

and a long-term increase since then (Luterbacher *et al* 2004), which was at least partly caused by external forcing (Hegerl *et al* 2011a) and therefore ‘natural variability’ may be different from internal variability. A further interesting question in attempts to provide a climate-based proxy for impacts of climate change is: to what extent does the rapidity of change matter, and how does it compare to trends due to natural variability? It is reasonable to assume that fast changes impact ecosystems and society more than slow, gradual ones. Also, is it really the mean seasonal temperature that counts, or should the focus change to extremes (see Hegerl *et al* 2011b)? Is seasonal mean exceedance of the prior temperature envelope a good and robust measure that also reflects these other, more complex diagnostics? Lots of food for thought and research!

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